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ABSTRACT

This study describes children's learning in a free-choice environment. Teacher controlled instruction is minimized and children participate in a wide variety of science activities with equipment that is selected by each individual student. The study occurs within an elementary school's Science Enrichment Center and the children work on the experiments suggested by activity sheets. The authors focus on an analysis of the ability of the students to work in the free-choice environment and learn to control variables in science experiments without instructions from the teacher. (Author/SA)

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A FREE-CHOICE ENVIRONMENT:

LEARNING WITHOUT INSTRUCTION

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A FREE-CHOICE ENVIRONMENT: LEARNING WITHOUT INSTRUCTION

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Introduction

This study describes children's learning in an environment where student autonomy is maximized and teacher controlled instruction minimized. The research is concerned with the manner in which upper elementary children learn about controlling variables, a concept fundamental both to science and everyday decision making. Children had the opportunity to learn through a wide variety of carefully designed science activities and materials from which they freely chose. The adult leader was a paraprofessional whose role was purposely restricted to exclude any teaching or direction of student learning activity.

In order to control variables it is necessary to equalize the effect of all other experimental variables over two or more trials and to manipulate the one under consideration. This strategy permits isolation of a single, cause-effect relationship from all other possibilities. Though this process may appear simple on the surface, realization of

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of the necessity to control variables when comparing experimental outcomes and the application of this concept are not easily acquired.

The research of Inhelder and Piaget (1958)[1] concerning the development of children's ability to think logically about controlling variables describes a progressive understanding of the concept during the preadolescent-adolescent period. Subsequent studies by others indicate that a significant segment of the student population have difficulties in reasoning when faced with the concept of controlling variables. Among high school students, understanding of the notion is frequently lacking and not easily corrected at that stage (Levine and Linn, in press).[2]

The purposes of this study were twofold: To find out how children operate in a free-choice environment and to discover what children learn about controlling variables in the absence of direct teacher instruction. It was also of interest to establish baseline data for subsequent studies designed to explore the effects of various modes of teacher intervention in combination with the free-choice program.

The Free-Choice Environment

Results from two previous, closely related studies (Linn, Chen, and Thier, 1976;[3] Linn, Chen, and Thier, 1976;[4]) indicated that a free-choice environment would be more appropriate as an enrichment program located outside the regular classroom and supplemental to the ordinary curriculum. Consequently, the free-choice environment established for this study, the Science Enrichment Center, was situated in an elementary school book-storage room. The children's work space for setting up

experiments consisted of two long tables and the floor space. All experimental apparatus unique to a particular activity, plus student activity sheets, were placed in labeled, five-gallon ice cream cartons located on shelves that were easily accessible to the children. Fifteen different activities were available to the children for experimentation at any one time from a total of fifty used in the study. Colorful posters on the wall advertised current activities that could be chosen.

Figure 1 shows a typical student activity sheet for one of the activities. It will be noted that the form (1) suggests an interesting activity, (2) describes a solution, (3) asks questions concerning experimental variables, and (4) provides the learner with a related challenge to solve.

Insert Fig. 1 (Catapult)

Report forms , shown in Figure 2, were available for the children at the completion of work with a particular set of equipment.

Insert Fig. 2 (Experiment Report)

The adult hired to work in the Science Enrichment Center was a paraprofessional who had no teacher training or previous classroom experience.

She was given the following instructions concerning her role:

1. Take attendance at each session and post the names of absentees to remind them to make up the missed time.
2. Sit somewhere in the room where the children can be observed; note on separate cards which activities each is working on, how much time is spent, and whether the child works singly or with partners.
3. Make sure that an Activity Report Form is completed before a child begins to work on a new activity.
4. Do not initiate conversation with the children.
5. Try to answer all questions by encouraging the children to find the answers and/or equipment independently.
6. Ask a child to leave the Center if he or she continuously disrupts others.

The paraprofessional gave the following instructions to the children at their first Science Enrichment Center session:

1. Choose any activities you wish while you are in the Enrichment Center.
2. Work as long as you wish with the equipment.
3. Work with friends or alone, but if you work with someone, each of you must set up the experiment (there was enough material for three children to work simultaneously on a single activity).
4. Complete an experimental report form when you finish an activity and give it to me.
5. Clean up your equipment and put it away when you are finished.

A total of ninety middle-class children representing the entire sixth grade of a suburban elementary school located in Orange County, California participated in the study. Forty-five of these children were randomly selected to attend the Science Enrichment Center, and comprised the Experimental Group. The remaining children were the Control Group. There were no significant differences in I.Q. or age between the Experimentals and Controls. The children in the Experimental Group attended the Center in groups of eight for two forty-five minute sessions per week for twelve weeks.

Evaluation of the Free-Choice Environment

Four kinds of data were gathered in this study in order to evaluate the effects of the Science Enrichment Center: (1) Video tapes of the Center in operation; (2) on-site observations of the paraprofessional and the children; (3) an attitude survey; and (4) tests measuring the student's ability to control variables.

Video Tapes. Ninety minutes of video taping recorded both the video and audio behavior of the children and the paraprofessional working in the Center. The tapes were made during the seventh week of the twelve-week session and were used to evaluate the degree of autonomy existing in the free-choice environment.

Site Observations. There were two sources for this data. During the fifth and tenth weeks of the Center's operation, the authors spent a total of twelve hours observing and recording the behavior of the paraprofessional and children. This was used in conjunction with the video data to determine the nature of the paraprofessional's role in the free-choice environment.

During the operation of the Enrichment Center, the paraprofessional sat at one end of the room and recorded the following information for each child: (1) Date; (2) name of activity; (3) Whether the child did only the activity or also specific challenges; (4) the actual time the child spent on the activity and/or challenges, excluding the time used to select an activity, but including clean-up time; and (5) whether the child worked singly or with friends. This data was sent weekly to the authors who used it in combination with the video tape and their site observations to describe the children's behavior in the Center.

Attitude Survey. A seven-question, self-report attitude questionnaire was completed by the children at the midway point in the Center's operation. That data was correlated with observed behavior data to provide information concerning the children's feelings about working in a free-choice environment.

Measure of Student's Ability to Use Reasoning When Controlling Variables. No appropriate standardized tests were suitable for this specific research purpose, so two pencil-paper group tests and an individual interview test--both employed in previous studies to measure the understanding of variables and experimentation (Linn, Chen, Thier, 1976; [5] Bowyer, Linn, 1976 [6])--were modified and used.

The group pencil-paper tests, the Spheres Test and the Balloon Box Test, served as pre-tests and post-tests, and were given in a counterbalanced order. The two sub-groups within the Control and Experimental Groups are shown in Figure 3.

Insert Fig. 3 (Design for Pre-tests and Post-tests)

The procedure for both the Spheres and Balloon Box Tests was to bring in the apparatus for the test, identify each element, and demonstrate the equipment. The experimenter would then show a short film segment which gave a more detailed demonstration, read the first question, show a film illustration of the question, and then allow all the students to write their answers. This sequence was repeated for all three questions on the tests.

Figure 4 shows the equipment used in the Spheres Test.

Insert Fig. 4 (Spheres Equipment)

Variables presented to the children as possibilities that might make a difference in how far the target moves included: (1) The position from which the sphere was released; (2) the weight of the sphere; (3) the weight of the target; and (4) the color of the sphere.

Figure 5 shows the equipment used in the Balloon Box Test.

Insert Fig. 5 (Balloon Box Equipment)

Variables presented to the children as possibilities that might make a difference in how far the box traveled included: (1) The amount of air in the balloon; (2) the number of straw; (3) the size of the hole in the box; and (4) the color of the balloon.

Two people independently scored each of the children's test papers. Interrater reliability was estimated at 92% with differences resolved by discussion. The criteria used for scoring both tests were identical. The following are the different response levels for the questions with examples selected from the Spheres Test:

Questions 1 and 2 (Can the child propose and explain a controlled experiment to answer an experimental question?)

> Level A - Included all incorrect responses. Example: "I will release the heavy sphere from the high position and the light one from the low position, so the heavy one will have a better chance to hit it (the target) farther away."
>
> Level B - Included two types of responses. In one, the children controlled the variables, but their explanation for setting up the controlled experiment focused on the outcome of the experiment rather than the necessity for all things to be equal. In the second type, the effects of variables were compensated for. Example: "I will release them both from the high position, because it (the target) will go farther." "I will put the light one (sphere) on the high (position) so they will come out even."
>
> Level C - Responses demonstrated that the children could control variables and explain why it was necessary to do so. Example: "You have to release them (the spheres) from the same position or you could not find out which is better."

Question 3 (Can the child recognize and explain the limitations of an uncontrolled experiment?)

Level A - Failed to criticize the experiment as uncontrolled.

Level B - Critcized the experiment as uncontrolled, but mentioned only one of the uncontrolled variables as a reason for the invalidity of the results.

Level C - Correctly criticized the experiment by mentioning all uncontrolled variables as reasons for the invalidity of the results.

A total categorical score was given for each test and was determined according to the following criteria:

Consistently did not control variables: Only Level A and/or B responses given to all three questions; Level A responses given to two questions and a Level C response given to the third question.

Inconsistently controlled variables: Level A or B responses given to one question and Level C responses given to the other two questions; Level C response given to one question and Level B response given to the other two questions.

Consistently controlled variables: Level C response given to all three questions.

The second test used to measure a student's ability to use reasoning when controlling variables was an individual interview. An adaptation of the Piagetian Bending Rods Task, described by Inhelder and Piaget (1958), [1] was used. It was given only as a post-test for the purpose of examining in more detail the ability to actually design and carry out experiments with concrete materials. Each child was interviewed for approximately fifteen minutes by one of two experimenters who were not informed whether the interviewee came from the Experimental or Control Group.

In the interview, the child was presented with six flexible rods protruding from a stand and varying in length, width, shape of cross-section, and material. Weights to be hung from the rods were demonstrated and then given to the child for use in setting up experiments

to determine the effects of the five variables on the bending of the rods. The Piagetian clinical interview technique of questioning experimental manipulations and suggesting counter-experiments characterized the interview and provided data for the experimenter's evaluation of the child's thinking. Responses were assigned to the following categories:

Category 1: Sets up controlled experiment for weight, but not for other variables.

Category 2: Sets up controlled experiments for weight and length, but not for other variables.

Category 3: Sets up controlled experiments for weight, length, and for either shape, material, and/or thickness, but not for all five variables.

Category 4: Sets up controlled experiments for all variables.

Results and Discussion

Analysis of the video tapes and site observations substantiated the fact that children operated in a free-choice, non-teacher-directed environment. In terms of teacher-talk, the paraprofessional in the Science Enrichment Center provided a sharp contrast to the teacher controlled classroom. Research shows that two-thirds of traditional classroom talk is done by the teacher, of which fifty percent consists of presenting information, opinions, directions, and criticisms (Flanders, 1963).[6] Through the use of video tape and on-site observation in the Center, it was estimated that the paraprofessional's contribution to the total amount of talk was five percent.

Examples of paraprofessional-initiated talk are typified in the following: (1) "You have about two minutes to clean-up"; (2) "Hey

you guys, I know you're having fun, but Lynn and Danny need the magnets to finish their experiment." Two examples of student talk that the paraprofessional responded to are: (1) "Mrs. Wilson, will you turn it over (sand clock) and tell us when forty seconds is up?" (Two children who happened to be sitting next to Mrs. Wilson and couldn't watch the sand clock and their experiments simultaneously); (2) "I can't find any thick metal like it says to use to make the alarm." (Student misread the word "thin" on the activity sheet as the word "thick"). Mrs. Wilson obliged both of these children.

For the most part the children assumed their autonomous role with ease. This can be largely attributed to the activity sheet design and equipment, refined in previous studies (Linn, Chen, and Thier, 1976) [3]. Educators who came to the Enrichment Center to observe invariably remarked on the business-like manner in which the children worked.* Although the children were extremely busy while in the Center, there were decided differences in the way individuals operated and felt within the environment. For example, there was a fairly wide range among individuals in terms of the amount of time spent working on a particular activity. On the average, children spent twenty-six minutes per activity. However, some averaged ten minutes while others averaged forty-five. An indication of the children's diligence in the Center can be inferred from the fact that on the average, only twenty-three percent of the children's time was spent in a non-working capacity, that is, without an activity in front of them with which they were occupied. During this time which amounted to approximately ten

* Dr. Robert Karplus, private communication.

minutes per session, decisions regarding activity choice were being made.

In terms of student preferences for independence in carrying out experiments, again there was a diversity of style. It will be recalled that the activities contained questions with solutions as well as challenges with no solutions. The latter provided the students with much greater autonomy and were more cognitively demanding. Because it had been found that on the average children did not choose to do the activity challenges (Linn, Chen, Thier, 1976) [3], in this study a reward consisting of a pass to the Lawrence Hall of Science was given to each student who completed six challenges. Eighty-five percent of the students, under these conditions, completed at least six challenges. This represented one-third of their total activity work time. In contrast, twenty percent of the students chose more often to do challenges than activities provided with immediate solutions. Students who did not complete six challenges for their reward had a lower than average attendance record (mean sixty-one percent of the classes attended compared to the overall mean of seventy-seven percent attendance) and indicated a negative attitude toward the Center on their attitude preference form.

About one-third of the children worked in pairs or trios instead of alone. This number varied according to the group, but it was observed that, in general, children who chose to work together kept the same partners over several activity periods. Contrary to expectations, working alone was not necessarily a verbally isolating experience. Typically, the single student shared the excitement of a particular

aspect of an experiment with a "next door neighbor" who might or might not respond depending on the current state of his or her own experiment. Surprisingly, the need to share the excitement did not appear to necessitate a response or supporting statement such as is frequently noted in research on student-teacher dialogue (Flanders, 1963).[6] Another interesting observation was individual children carrying on extended oral discussions with themselves and/or their activity sheets, totally and unselfconsciously absorbed in their work.

In general, the students liked the Enrichment Center. This is evidenced by data from a questionnaire in which two-thirds of the students indicated a desire to attend the Center more often than twice a week. Many of these students came in during recess and free class time in addition to their scheduled sessions. It is interesting, however, that seventeen percent of the children wished to come to the Center less often or not at all. In fact, in spite of strong encouragement and provisions for make-up sessions, twelve percent of the students missed more than half of the classes (not due to school absences). In individual interviews with these children, the most common reason given for not attending the Center was that they had to make up all work missed in their regular class when they attended the Center and they had trouble getting it all finished.

On the attitude questionnaire the most frequently mentioned negative aspect of the Enrichment Center was the necessity to complete Activity Report Forms. In the first sessions of the Center the reports were brief and became briefer as the twelve weeks progressed. A follow-up experiment with the Control Group investigated alternative methods

of reporting experimental results. Students were given the following choices concerning the form used to report the results of each activity: (1) Write responses to the questions on the Experiment Report Form (Figure 2); (2) Orally answer the questions on the Experiment Report Form as asked by the paraprofessional; (3) Orally answer the Experiment Report Form questions directly into a tape recorder. It was found that during a twelve-week Enrichment Center Session eighty-nine percent of the total number of reports were written, three percent were given orally in response to the paraprofessional's questioning, and eight percent were given directly into a tape recorder. Only fifty-five percent of the students tried either of the two oral reporting options and of those who did, few adopted the mode permanently. It appears that the necessity to report experimental results is viewed negatively by the children regardless of the form of the reporting. The resistence of children to reflect on their experimental activity needs to be looked at further, not only to understand the source of their dislike, but also to determine the long-term value of such activity.

The most positive aspect of the Enrichment Center was "doing the experiments." It will be noted, however, that some children began to be bored with the activities available about midway through the twelve-week set of Enrichment Center sessions. The addition of new activities alleviated this problem for some, but a few students were very selective about what they liked and didn't like. For these children the boredom problem continued. It appears that individual differences exist in children regarding the free-choice learning environment. Future studies need to focus on identifying characteristics of learners

who are and are not able to effectively operate in this type of learning situation.

Test Data

The X^2 test for two independent samples revealed no initial differences between the Experimentals and Controls. Figure 6 shows the distributions of pre-test scores in percentages for the two subgroups.

Insert Figure 6 HISTO

As can be observed, more than sixty percent of the students within all subgroups did not control variables. Less than thirty-two percent controlled inconsistently and an insignificant number of students consistently controlled variables.

Post-test performances of the two experimental groups were significantly different than the controls as is shown in Figure 7. The X^2 of 42.5 for the subgroup receiving spheres as a post-test was significant at the .01 level. The X^2 of 39.5 for the subgroup who received Balloon Box as a post-test was significant as the .01 level. In Figure 7 is shown the distribution of the post-test scores in percentages for the two subgroups.

Insert Figure 7 HISTO

Fifty-four percent of the children in one Experimental subgroup, and fifty percent in the other inconsistently controlled variables. Very few children controlled variables consistently. The shapes of the distributions of the post-test performances for the Control subgroups remained similar to their pre-tests.

Figure 8 shows the distribution in percentages of post-test scores for the combined Experimental and Control subgroups.

Insert Figure 8 HISTO

As can be seen, a major change between pre-test and post-test occurred for the Experimentals from the "Didn't control variables" category to "Inconsistently controlled variables."

Figure 9 shows the distribution of scores for the Bending Rods Interview Test.

Insert Figure 9

The Mann-Whitney U Test was used to test for statistical differences between the Experimental and Control Groups' category scores. It will be noted that both the Experimentals and Controls were able to set up controlled experiments to prove that the heavier the weight the more the rod bends. However, thirty-two percent more Experimentals were able to set

up controlled experiments for three variables (category 3) and nineteen percent of them controlled five variables in the experiment (category 4) in contrast to none for the Control Group.

It is interesting to note the contrast in sensitivity between the group pencil-paper tests and the individual interviews. The group tests revealed that the program resulted in transferring approximately one-third of the Experimental population from a state in which they were unable to recognize the necessity for controlling variables to one in which they evidenced some understanding for the need to control experiments. In contrast, the individual test indicated that well over two-thirds of the Experimental Group (78%) understood the necessity for controlling experiments, particularly when the variables were familiar such as length and weight. The variation in these results is compatible with Piaget's theoretical explanation that the concrete operational learner is able to separate variables and perform controlled experiments when working with the apparatus for an experiment, whereas the formal operational learner can separate and control variables even when presented with an unfamiliar problem and without apparatus. Inhelder and Piaget characterize this transition from the concrete to formal as a change from exploring real results to anticipating possible results (1958).[1]

Implications

This study provides evidence for the fact that sixth grade, middle-class children can work constructively, efficiently, and with enthusiasm over an extended period of time in an environment which encourages student autonomy. Children can make decisions concerning choice of activity,

organization of work time, and degree of cognitive involvement with materials. In addition to being able to operate effectively in a free-choice environment, there is evidence that children can learn about controlling variables--an area which requires an advanced level of logical thinking.

Autonomy coupled with learning possesses significant implications for classroom organizational models currently being tested. For example, teachers are increasingly assuming the role of supervising and directing the activities of parent-aides and paraprofessionals in their classrooms (California Agency for Research in Education, 1975).[7] The fact that a paraprofessional can be directly involved in children's activities which have significant educational impact is, therefore, extremely important.

It is particularly interesting to learn that children are able to grow in their understanding of one of the major concepts in science without the involvement of a teacher. Science continues to be a neglected area of the elementary school curriculum in spite of enormous efforts on the part of many, including the Federal Gvoernment, to change the situation. Perhaps it is possible to expose more children to science by using supplemental programs and paraprofessionals in a paradigm similar to that used in this study. Of course, the more interesting question is what additional growth in logical thinking and understanding of science could take place if the child was exposed to a meaningful teacher-led classroom science program and the opportunities to participate in an enrichment center-like experience. Future research will explore this and other questions.

Figure 1

CATAPULT

ACTIVITY: Use the catapult to throw a plastic rectangle 20 cm.

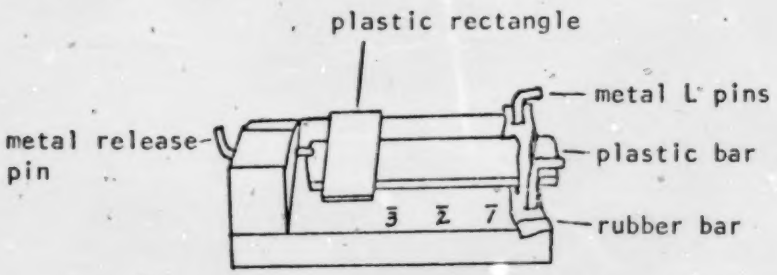
MATERIALS

catapult
rubber bar
metal arch
1 plastic rectangle
meter tape

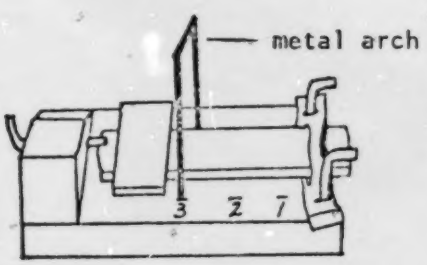
For Challenge
rubber band
1 metal rectangle
1 wooden rectangle

DIRECTIONS

1. Set up on the floor the equipment as shown in the picture.



2. Place the metal arch in the #3 hole as shown.



3. Use the catapult to throw the plastic rectangle by releasing the plastic bar with the metal release pin. How far did it go? _____

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4. Experiment with the arch in the #2 and #1 holes. Did the rectangle travel farther with the arch in position 1, 2, or 3 ? (Circle one.)

CATAPULT CHALLENGE #1: See if you can get a wooden rectangle to go the same distance as a plastic rectangle.

Show how you solved the challenge.

CATAPULT CHALLENGE #2: Find out whether a rubber band or the rubber bar catapults the metal bar farther.

Show how you solved the challenge.

CATAPULT CHALLENGE #3: Try to devise a method to find out the path in the air of the rectangles. Draw what you think the path is.

Show how you solved the challenge.

Figure 2

EXPERIMENT REPORT

Name _____

NAME OF ACTIVITY OR CHALLENGE _____

1. What I wanted to find out from this experiment when I started working:

_____

_____

2. A description of my experiment in words and/or pictures:

_____

_____

_____

_____

_____

_____

_____

3. Variables (things) I tried to find out about in my experiment:

_____

Variables (things) I kept the same in my experiment:

_____

4. What I found out from this experiment:

_____

_____

_____

_____

Figure 3: Design for Pre-tests and Post-tests

GROUP		PRE-TEST	POST-TEST
Control	A	Spheres Test	Balloon Box Test
	B	Balloon Box Test	Spheres Test
Experimental	A	Spheres Test	Balloon Box Test
	B	Balloon Box Test	Spheres Test

Figure 4

Balloon Box Test Equipment

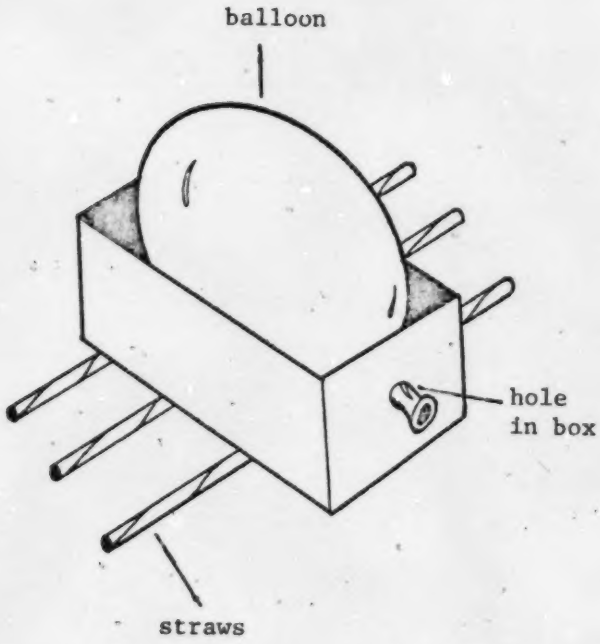

Figure 5

Spheres Test Equipment

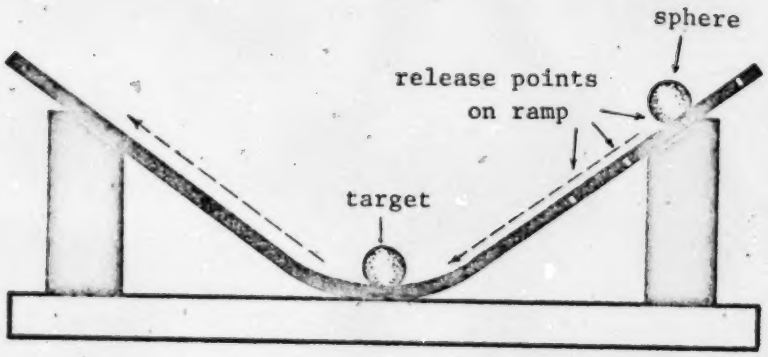

Figure 6: Distribution of pre-test scores in percentages for Spheres and Balloon Box Tests

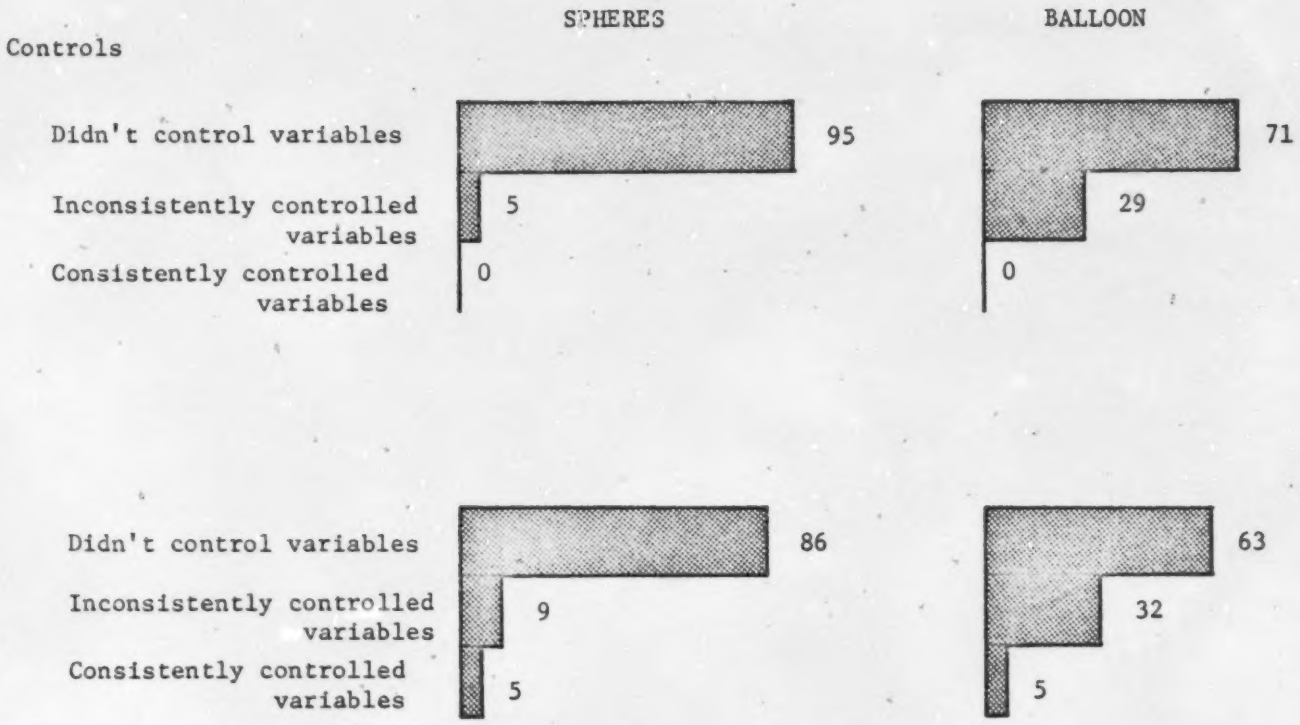

Figure 7: Distribution of pre-test scores in percentages for Spheres and Balloon Box Tests

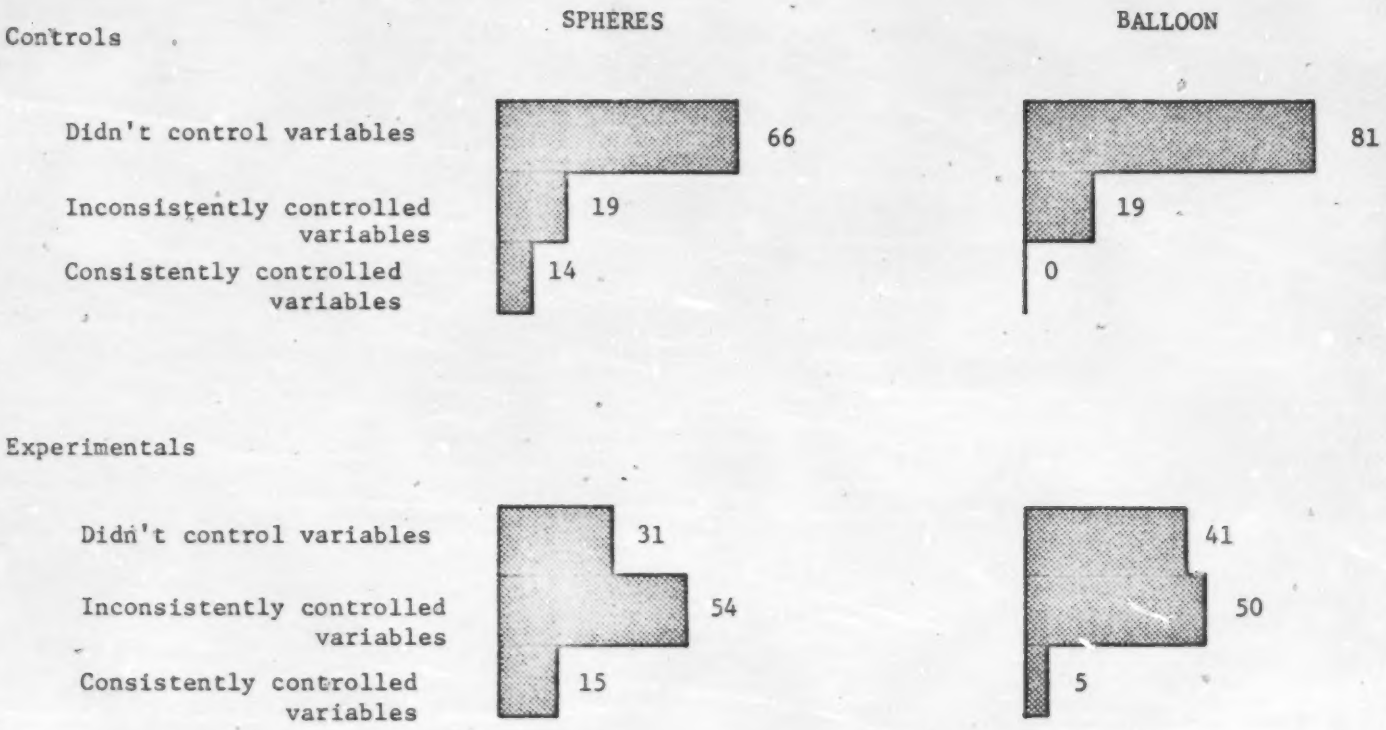

Figure 8: Distribution of combined subgroups' post-test scores in percentages for the Experimentals and Controls

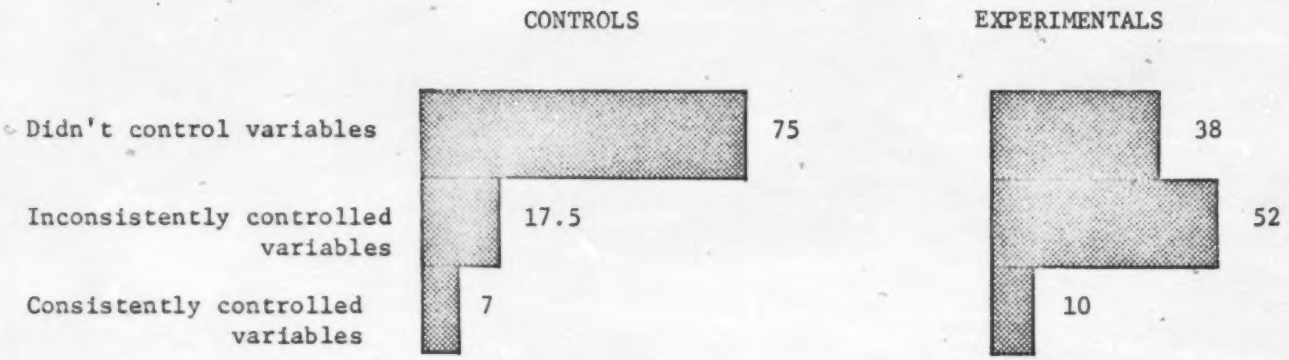

Figure 9: Percentage scores for the Bending Rods Individual Interview Tests

	Experimentals (N=37)	Controls (N=33)	Percentage Difference
Category 1	0%	6%	+6
Category 2	22%	67%	+45
Category 3	59%	27%	+32
Category 4	19%	0%	+19

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NOTE: Numerals following cited material in the text correspond to the numerals appearing before each bibliographical entry below.

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